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12-05-03

Attorney Docket No. 01-IND-243
Client Matter No. 19204.0002

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No. 10/618,440
Applicant: Rohit DUBEY
Filed: July 10, 2003
TC/A.U. 2133
Examiner:
Docket No. 01-IND-243
Customer No. 25235

Confirmation No. 4206
Title: BOUNDARY SCAN OF
INTEGRATED CIRCUITS

CERTIFICATE OF MAILING BY EXPRESS MAIL

Commissioner for Patents
P.O Box 1450
Alexandria, VA 22313-1450

Sir:

The undersigned hereby certifies that the following documents:

1. Transmittal of Certified Copy of Priority Document;
2. Certified Copy of Priority Document;
3. Certified Copy of Form 13--Annex to Priority Document;
4. Return Card, and

this Certificate of Mailing relating to the above application, were deposited as "Express Mail," Mailing Label No. EL533429096US with the U.S. Postal Service, addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, on December 3, 2003.

December 3, 2003

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December 3, 2003

Carol W. Burton, Reg. No. 35,465
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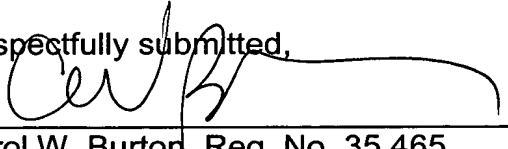
Enclosed is a certified copy of the India Application No. 783/Del/02 from which priority under 35 U.S.C. § 119 is claimed.

Also enclosed is a certified copy of Form 13--Annex, to the priority document, which amends inventorship of the priority India case.

Should you have any questions regarding the enclosed, please contact the undersigned.

December 3, 2003

Respectfully submitted,



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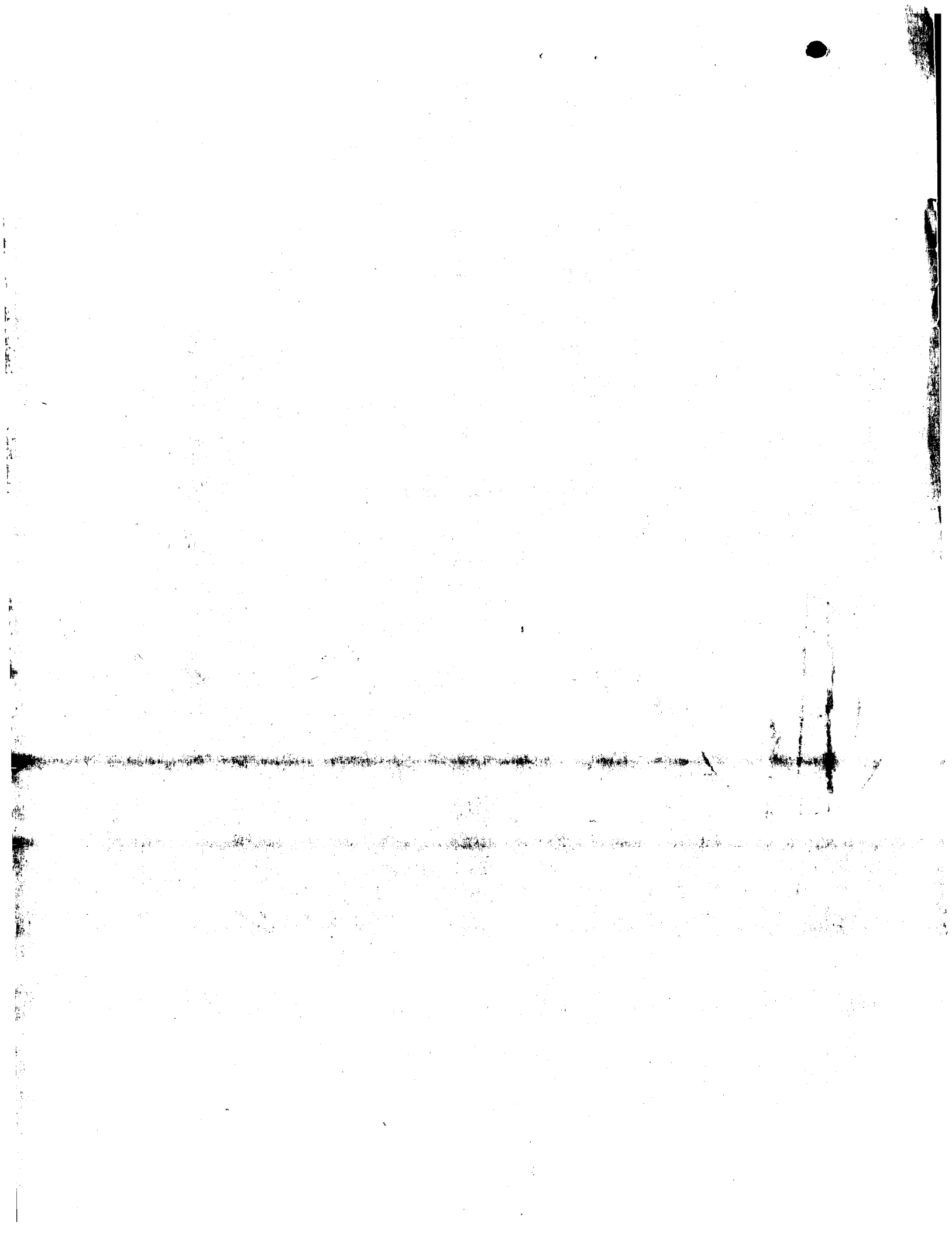
GOVERNMENT OF INDIA
MINISTRY OF COMMERCE & INDUSTRY,
PATENT OFFICE, DELHI BRANCH,
W - 5, WEST PATEL NAGAR,
NEW DELHI - 110 008.

*I, the undersigned, being an officer duly authorized in accordance with the provision of the Patent Act, 1970 hereby certify that annexed hereto is the true copy of the **Application, Complete Specification and Drawing Sheets** filed in connection with Application for Patent No. 783/Del/02 dated 29th July 2002.*

Witness my hand this 29th Day of July 2003.

A handwritten signature in black ink, appearing to read 'K.S. Kardam', written over a horizontal line.

(K.S. KARDAM)
Assistant Controller of Patents & Designs



0703-2

FORM 1
THE PATENTS ACT, 1970
(39 of 1970)

29 JUL 2002

APPLICATION FOR GRANT OF A PATENT
(See Sections 5(2), 7, 54 and 135)

1. We, *STMicroelectronics Pvt. Ltd., Plot No. 2 & 3, Sector 16A, Institutional Area, Noida - 201 3001, Uttar Pradesh, India, an Indian Company*

2. hereby declare -

↔ (a) that ~~I am~~/we are in possession of an invention titled "*Improved boundary scan of Integrated Circuits?*"

(b) that the provisional / complete specification relating to this invention is filed with this application

(c) that there is no lawful ground of objection to the grant of a patent to me/us.

3. further declare that the inventor(s) for the said inventions is/are

i. **BAJAJ, Rajesh**, an Indian national of (please insert complete address)

ii. **PADHA, Nipun**, an Indian national of (please insert complete address)

4. We claim the priority from the application(s) filed in connection countries, particulars of which are as follows: Nil

5. We state that the said invention is an improvement in or modification of the invention the particulars of which are as follows and of which we are the applicant/patentee: NIL

6. We state that the application is divided out of ~~my~~/our application, the particulars of which are given below and pray that this application be deemed to have been filed on under section 16 of the Act. NIL

7. That ~~I am~~/we are the assignee or legal representative of the true and first inventors N.A

8. That ~~my~~/our address for service in India is as follows:

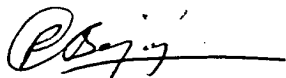
ANAND & ANAND, Advocates
B-41, Nizamuddin East
New Delhi - 110 013
Tel Nos.: (11) 4358078, 4355076, 4350360
Fax Nos.: (11) 4354243, 4353060

9. We the true and first inventors for this invention ~~or the applicant(s) in the convention country~~ declare that the applicant(s) herein is/are ~~my~~/our assignee or legal representative

DUPLICATE

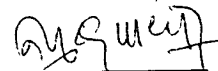
i. **BAJAJ, Rajesh**, an Indian national of *B 2/59 SAFDARJAUNG ENCLAVE*
New Delhi - 110029

ii. **PADHA, Nipun**, an Indian national of *L-132 Sector 25*
NOIDA (UP) Pin 201301.



BAJAJ, Rajesh

Dated this 18th day of July, 2002



PADHA, Nipun

10. that to the best of my/our knowledge, information and belief the fact and matters stated herein are correct and that there is no lawful ground of objection to the grant of patent to me/us on this application.

11. Followings are the attachment with the application:

(a) Complete specification (3 copies)

(b) Abstract (3 copies)

(c) Formal Drawings (3 copies)

(d) Power of attorney

(e) Application form 1 (3 copies)

(f) Form 3 (in duplicate)

(g) Fee Rs. 5000/- cheque bearing no. , dated on
Bank.

I/we request that a patent may be granted to me/us for the said invention

Dated this 29th day of July, 2002

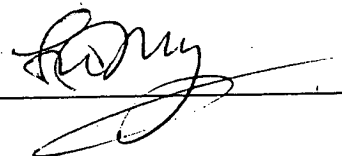
STMicroelectronics Pvt. Ltd.

(Mr. K.J. Foo)

(Financial Controller)

To

The Controller of Patents
The Patent Office, at Delhi



Form 2

0 7 0 0 2
THE PATENTS ACT, 1970

29 JUL 2002

COMPLETE SPECIFICATION

[See Section 10]

REPLICA

'IMPROVED BOUNDARY SCAN OF INTEGRATED CIRCUITS'

*STMicroelectronics Pvt. Ltd., Plot No. 2 & 3, Sector 16A, Institutional Area, Noida – 201
301, Uttar Pradesh, India, an Indian Company*

The following specification particularly describes and ascertains the nature of this invention and the manner in which it is to be performed.

Field of the invention:

This invention relates to the field of integrated circuits. More specifically the invention relates to the boundary scan test of integrated circuits.

Background of the invention:

As integrated circuits become more complex, it becomes increasingly necessary to implement thorough testing for verifying functionality and conformance to specifications. At the same time the shrinking size of integrated circuits as well as the accelerating speed requirements of devices have propelled the development of smaller and faster testing methods. Various standards bodies have also been involved in developing test standards in an effort towards promoting standardization of test methods. To this end a "boundary-scan" testing specification was proposed and developed by the Joint Test Action Group (JTAG) which was later standardized as the IEEE standards 1149.1 specification. This boundary-scan test architecture offers the capability to test components efficiently whether embedded in assembled printed circuit board assemblies or in the form of integrated circuit devices.

The Boundary Scan Test architecture is capable of testing pin connections without using physical test probes. It is also capable of capturing functional data while a device is in normal operation. The boundary scan process can force signals onto pins, or capture data from pin or core logic signals. Captured test data is serially shifted into special boundary scan cells from where it can be serially shifted out and compared to expected results externally.

Boundary scan register cells are placed such that the state of each digital system pin can be controlled or observed using the boundary scan register. These cells may also allow the state of the system logic inputs and outputs to be controlled and observed respectively.

While the implementation of conventional IEEE 1149.1 compliant interfaces within components, such as integrated circuit chips, facilitates higher quality, low cost testing without the need for disclosure of the internal circuitry of the components under test, these benefits come at the expense of performance due to the signal path delay associated with boundary scan cells. Because of the performance penalty associated with conventional

IEEE1149.1-compliant boundary scan cells manufacturers have resisted compliance with the IEEE1149.1 standard.

US Patent 6266793, proposes a method for boundary scanning with increased testability by adding one extra signal to the standard methods, so that input buffers and output buffers are also testable in a two bit bi-directional boundary scan cell. However this method can not be implemented with the standard "INTEST" instruction defined by IEEE standard 1149.1.

The Summary of the Invention:

The object of this invention is to provide a method and device for boundary scan testing of integrated chips, in a manner that fully conforms to the IEEE standard 1149.1 in an efficient manner and in a small size.

Another object of this invention is to increase the operational speed of the boundary scan test process.

To achieve these and other objectives this invention provides an improved 2-bit boundary scan test circuit capable of applying boundary scan test vectors to the input of the core logic of a circuit, using a multiplexer for selectively coupling the output of a boundary scan register to the input of a boundary scan register or to the input of the core logic, and a selection circuit for controlling the multiplexer to enable the coupling when test vectors are required to be applied to the core. The invention also provides a method for improving a 2-bit boundary scan test circuit to provide the capability of applying boundary scan test vectors to the input of the core logic of the circuit, by providing a multiplexing arrangement to enable the selective coupling of the output of a boundary scan test register to the input of the core logic, and an arrangement for selectively enabling the multiplexing arrangement for coupling the output of the boundary scan test register when the test vectors are required to be applied to the core logic.

Brief Description of the figures:

The invention will now be described with reference to the accompanying drawings

Figure 1 shows the schematic logic diagram of a prior art JTAG boundary-scan cell containing three bit bi-directional boundary scan cell.

Figure 2 is a schematic logic diagram of another prior art JTAG boundary-scan cell containing two bit bi-directional boundary scan cell.

Figure 3 shows schematic logic diagram of another prior art JTAG boundary-scan cell containing two bit boundary scan cell and enhanced testing capability.

Figure 4 shows schematic logic diagram of one embodiment of the boundary scan cell of the present invention having two bit boundary scan cell and added circuitry extends the use of boundary scan cell shown in FIG. 2 with every standard instruction.

Figure 5 is a logic schematic diagram of another embodiment of the boundary scan cell of the present invention with slight modification of FIG. 4 to enhance testability more than as in FIG. 3 using minimal signal and hard-ware.

Detailed Description of the invention:

The invention will now described according to the accompanying drawings. The present invention is illustrated by way of example, and is not limited to the specific implementations of the accompanying figures or description.

Figure 1 shows a circuit for realizing a boundary scan cell according to the IEEE std. JTAG specification. In the full IEEE JTAG implementation, the boundary scan cell includes an input portion, an output portion, and a scan cell portion for providing tri-state control. Multiplexer 111 selects data to be coupled to a JTAG output capture register 112 from either the core logic P_OUT circuitry of the IC or from a previous stage. The selection is controlled by signal shift/capture from control logic JTAG circuit coupled to multiplexer 111. The

capture register 112 can be loaded externally (from one of the five JTAG pins), or can capture data from one of the previous test clock cycles.

The **shift/capture** signal enables the data capture directly from the core logic **P_OUT**, **P_TS**, from the input buffer 125 or from the previous scanning stage. This last operation involves shifting all of the register stages of the boundary scan cell in a daisy chain. The JTAG data input pin is connected to the input of the first element **SCAN IN** in the daisy chain, and the output of the last element in the chain is connected to the JTAG output pin **SCAN OUT**. The registers get loaded during this process with data and can then be shifted until the desired stage has been reached.

An update register 113 is used on completion of shifting operation for proper alignment and presentation of the data at the output buffer 115. The output of register 113 is connected to one of the inputs of multiplexer 114, the second input of the multiplexer being connected directly to the core logic **P_OUT** with the output connected to buffer 115. Buffer 115 is controlled by signal line 116, and the output of the buffer is connected to pad 120 and routed to multiplexers 121, 124 through buffer 125. Buffer 125 is utilized to drive the voltage signal either the core logic **P_IN** of the IC via multiplexer 121, or to an input capture register 123. Multiplexer 124 selects either the input buffer 125, or the previous scan stage data captured in previous boundary scan cell. The selection is controlled by **shift/capture** signal. The output of multiplexer 124 connects to the input of capture register 123. The capture register 123 updates register 122, which can be routed back to the core logic via multiplexer 121. Multiplexers 121, 114, 134 are controlled by the **mode** signal. The signal 116 is the control signal for the buffer 115. The output of multiplexer 134 is the signal 116, which is either the captured data from control update register 133 or the control signal from the core logic **P_TS**. The input of control update register comes from control capture register 132. The control capture register selects between the tri-state signal from core, or data from previous scan stage through multiplexer 131. Multiplexer 131 is controlled by **shift/capture** signal.

This method for realizing a boundary scan design requires a substantial amount of circuitry which in turn increases the cost of operation, area of the chip, power consumption and introduces additional delays that reduce the speed of the device.

Figure 2 shows another prior art implementation of boundary scan circuitry that reduces the number of the registers used, in exchange for forgoing the INTEST capacity of the device. In this scan architecture only two capture registers 242, 252 are connected to the SCAN_IN input in a daisy connection through multiplexers 241, 251. The output SCAN_OUT of the capture register 252 serves as the line output for the serial scan of the daisy chained connection. The inputs of update registers 243 and 253 are connected to the outputs of capture registers 242 and 252 respectively. The outputs of the update registers 243, 253 are connected to the input of multiplexers 244 and 254. The output of multiplexer 244 is connected to the input of buffer 245 and the output 255 of multiplexer 254 controls buffer 245. The output of buffer 245 connects to pad 260, P_IN, and also serves as one of the inputs to multiplexer 240, through buffer 246. The core logic output P_OUT serves as the second input to multiplexers 240 and 244, while control signal P_TS serves as the second input to multiplexers 251 and 254. The second input to multiplexer 241 is the output of multiplexer 240. The select input of the multiplexer 240 is also the control signal of buffer 245. Multiplexers 241 and 251 share the same select control which also serves as the shift/capture pin. The select pins for the multiplexer 244, 254 are the MODE select lines. The MODE select line selects the mode of the operation of the device i.e. it determines whether the data is to be sent directly from the core to IO pad or visa-versa.

The operation of the circuit is similar to the operation of the circuit of **figure 1**. However this architecture is not capable of performing the INTEST function of the IEEE standard. Output buffer 245 is enabled by signal 255 that selects output data from core of IC for capture register 242 through multiplexer 240. Further the captured data can be connected to pad 260 through output buffer 245. When the output buffer is disabled by signal 255, the data coming from input buffer 246 can be captured in capture register 242. There is no mechanism for updating of the captured data to the core of IC which is needed for the INTEST instruction of IEEE JTAG standard 1149.1.

Figure 3 shows another prior art implementation of the boundary scan architecture offering improved testability and usability. This design enables testing of every path within the boundary scan cell. However the design results in an increased number of nodes. Gates 355

and 348 are introduced for providing extra control pins. Four signals **MODE_1**, **MODE_2**, **EXTEST***, and **CHIP_TEST*** are derived from JTAG decode circuitry. Control signal **EXTEST*** is set 0 when EXTEST instruction is to be selected and prevents off-chip test data from reaching the on-chip system logic through AND gate 348. Control signal **CHIP_TEST*** is set to 0 when the INTEST or RUNBIST instruction is selected, and set to 1 when SAMPLE/PRELOAD or EXTEST instruction is selected and the output buffer is enabled / disabled accordingly by AND gate 355. The **MODE_1** and **MODE_2** signals are controlled through JTAG decoder logic depending upon the instruction selected. Multiplexer 340 selects the output from multiplexer 347, or the output from multiplexer 344. Multiplexer 340 is controlled by the output signal from multiplexer 354. The capture of data through multiplexer 340 is controlled by **MODE_1** and **MODE_2**. This architecture requires several extra control signals, which results in extra hardware in JTAG decoder circuitry and occupies more routing area of the IC.

Figure 4 shows the schematic diagram of boundary scan architecture in accordance with the present invention. Two capture registers 442 and 452 are connected in daisy chain through multiplexers 441 and 451. The SCAN IN is connected to one of the inputs of multiplexer 441 and the SCAN OUT as the output of the capture register 452. The output of registers 442 and 452 are applied to the update registers 443 and 453 respectively the outputs of which are connected to the inputs of multiplexers 444 and 454. The output of multiplexer 444 is applied to the input of buffer 445 and the output 455 of multiplexer 454 controls buffer 445. The output of buffer 445 connects to pad 460, and also serves as one of the inputs to multiplexer 440, through buffer 446 and multiplexer 448. The output can also be connected as an input to the core logic **P_IN** through buffer 446 and multiplexer 448. The core logic output **P_OUT** serves as the second input to multiplexers 440 and 444, while control signal **P_TS** serves as the second input to multiplexers 451 and 454. The second input to multiplexer 441 is the output of multiplexer 440. The select input of multiplexer 440 is the control signal of buffer 445. Multiplexers 441 and 451 share the same select control, which serves as the shift/capture pin for the circuit. The select pin for multiplexers 444, 448 and 454 is the **MODE** select line which is also one of the select lines for multiplexer 448 while the second select line of multiplexer 448 is control signal 455 which serves as the select MSB for the multiplexer. This architecture is capable of implementing all the IEEE 1149.1 Std

instructions and tests while using only a two bit boundary scan cell, reducing one cell in terms of hardware, thereby providing a reduced scan chain and increasing the testing speed. This arrangement also provides for the simultaneous testing of EXTEST and INTEST instructions, resulting in increased testing speed. The output of multiplexer 448 is selected by signal 455 (msb) from multiplexer 454 and JTAG mode signal (lsb). The multiplexer 448 selects captured data, or data from input buffer for the core logic of the IC. At the same time multiplexer 440 always selects data coming from input buffer when the boundary scan cell works as input, enabling EXTEST and INTEST instructions to operate independently or simultaneously. This arrangement uses less area, and less hardware resulting in smaller size. At the same time the novelty of performing EXTEST and INTEST simultaneously reduces the testing time.

Figure 5 shows another embodiment of the present invention. In this embodiment two input multiplexer 440 of the figure 4 is replaced by a four input multiplexer 549 such that P_IN, P_OUT and output of the buffer 546 are the inputs of the multiplexer. The control signal of buffer 545 serves as one of the select lines while the second select line 557 is the logical output of the logic 556. The signal MODE_1 is the first input to the 2-input AND gate 556 and the second input is MODE_2. The main advantage of this embodiment is that it can test output buffers of bi-directional pads, which is not possible with any of the previous two bit boundary scan cell designs.

It will be apparent to those with ordinary skill in the art that the foregoing is merely illustrative and is not intended to be exhaustive or limiting, having been presented by way of example only and that various modifications can be made within the scope of the above invention.

Accordingly, this invention is not to be considered limited to the specific examples chosen for purposes of disclosure, but rather to cover all changes and modifications, which do not constitute departures from the permissible scope of the present invention. The invention is therefore not limited by the description contained herein or by the drawings, but only by the claims.

We claim:

1. An improved 2-bit boundary scan test circuit capable of applying boundary scan test vectors to the input of the core logic, comprising:
 - a multiplexing means for selectively coupling the output of a boundary scan register to the input of a boundary scan register or to the input of the core logic, and
 - a selection mechanism for controlling the multiplexing means to enable the coupling when test vectors are required to be applied to the core.
2. A method for improving a 2-bit boundary scan test circuit to provide the capability of applying boundary scan test vector to the input of the core logic, comprising the steps of:
 - providing a multiplexing arrangement to enable the selective coupling of the output of a boundary scan test register to the input of the core logic, and
 - selectively enabling the multiplexing arrangement for coupling the output of the boundary scan test register when the test vectors are required to be applied to the core logic input.
3. An improved 2-bit boundary scan test circuit as claimed in claim 1 further including an arrangement to self test the boundary scan circuit, comprising:
 - multiplexing means for selectively coupling the outputs of the scan output registers into the scan chain shift registers, and
 - a selection mechanism for enabling the multiplexing means for said coupling when required.
4. An improved 2-bit boundary scan test circuit capable of applying boundary scan test vectors to the input of the core logic substantially as herein described with reference to the accompanying drawings.

5. A method for improving a 2-bit boundary scan test circuit to provide the capability of applying boundary scan test vector to the input of the core logic substantially as herein described with reference to the accompanying drawings.

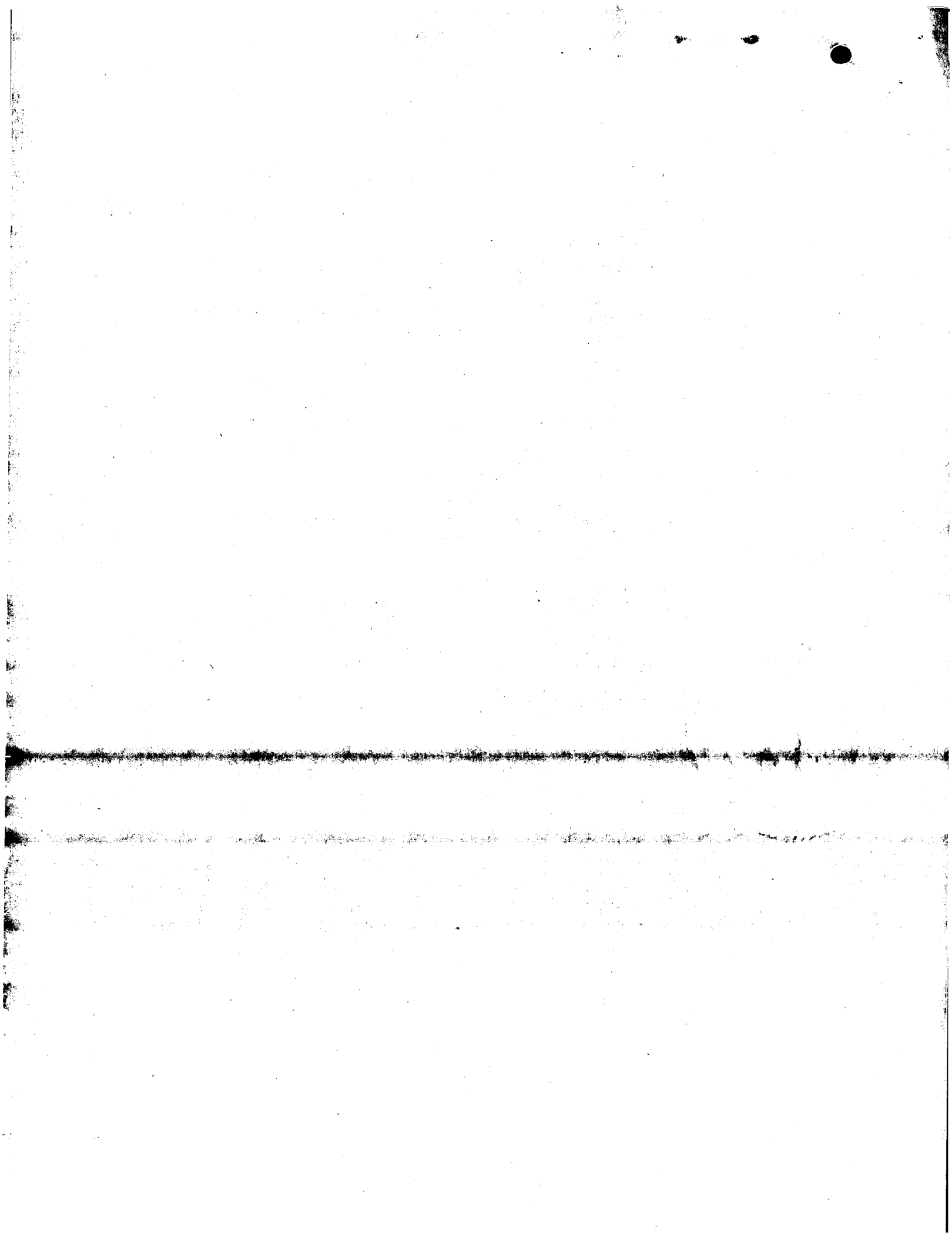
Dated this 29th day of July 2002



of ANAND & ANAND, Advocates
Agents for the Applicants

ABSTRACT

This invention relates to an improved 2-bit boundary scan test circuit capable of applying boundary scan test vectors to the input of the core logic of a circuit, using a multiplexer for selectively coupling the output of a boundary scan register to the input of a boundary scan register or to the input of the core logic, and a selection circuit for controlling the multiplexer to enable the coupling when test vectors are required to be applied to the core.



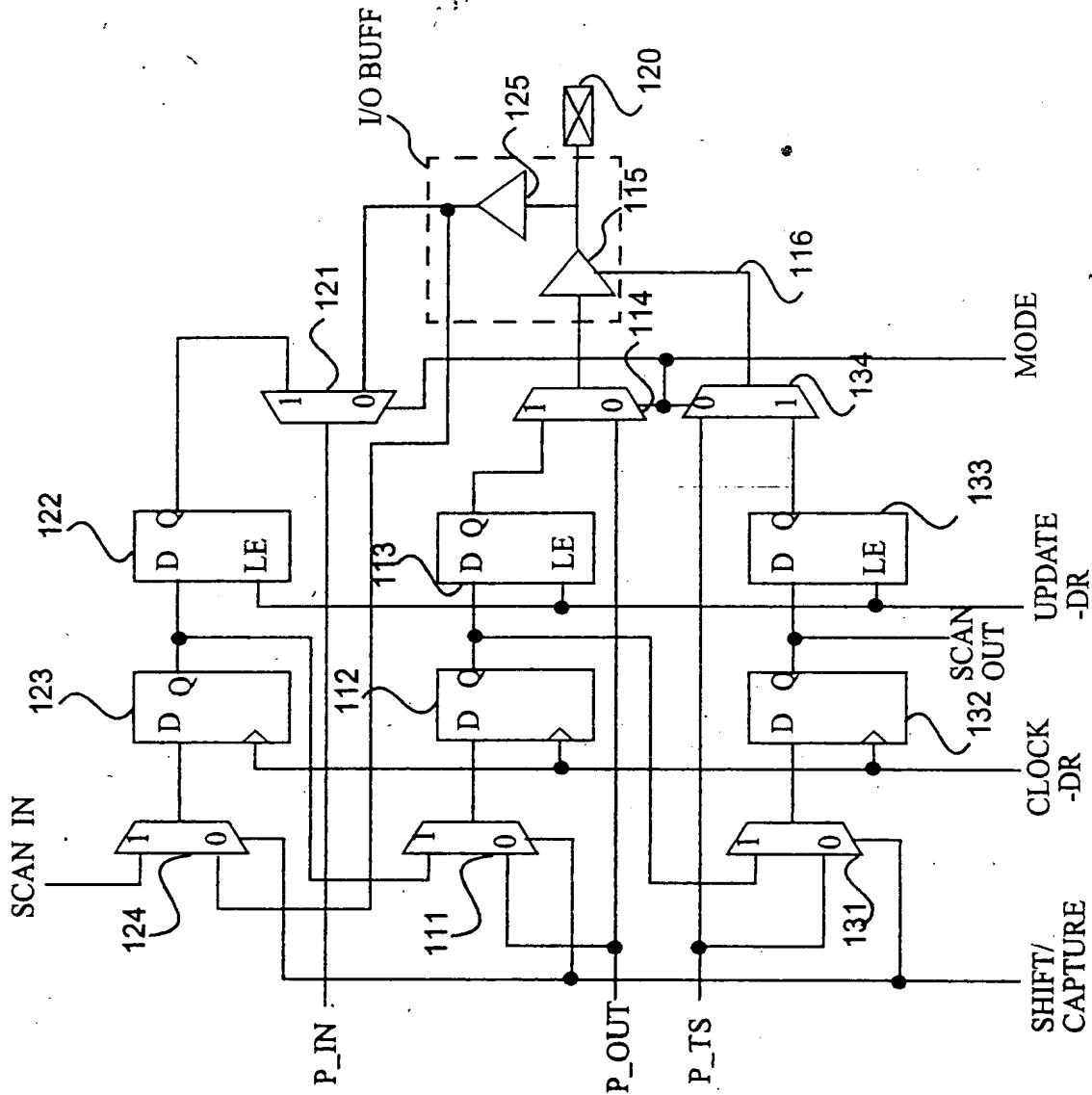


FIG. 1 (Prior Art)

[Signature]
Of Anand and Anand Attorneys
Attorney for the Applicant

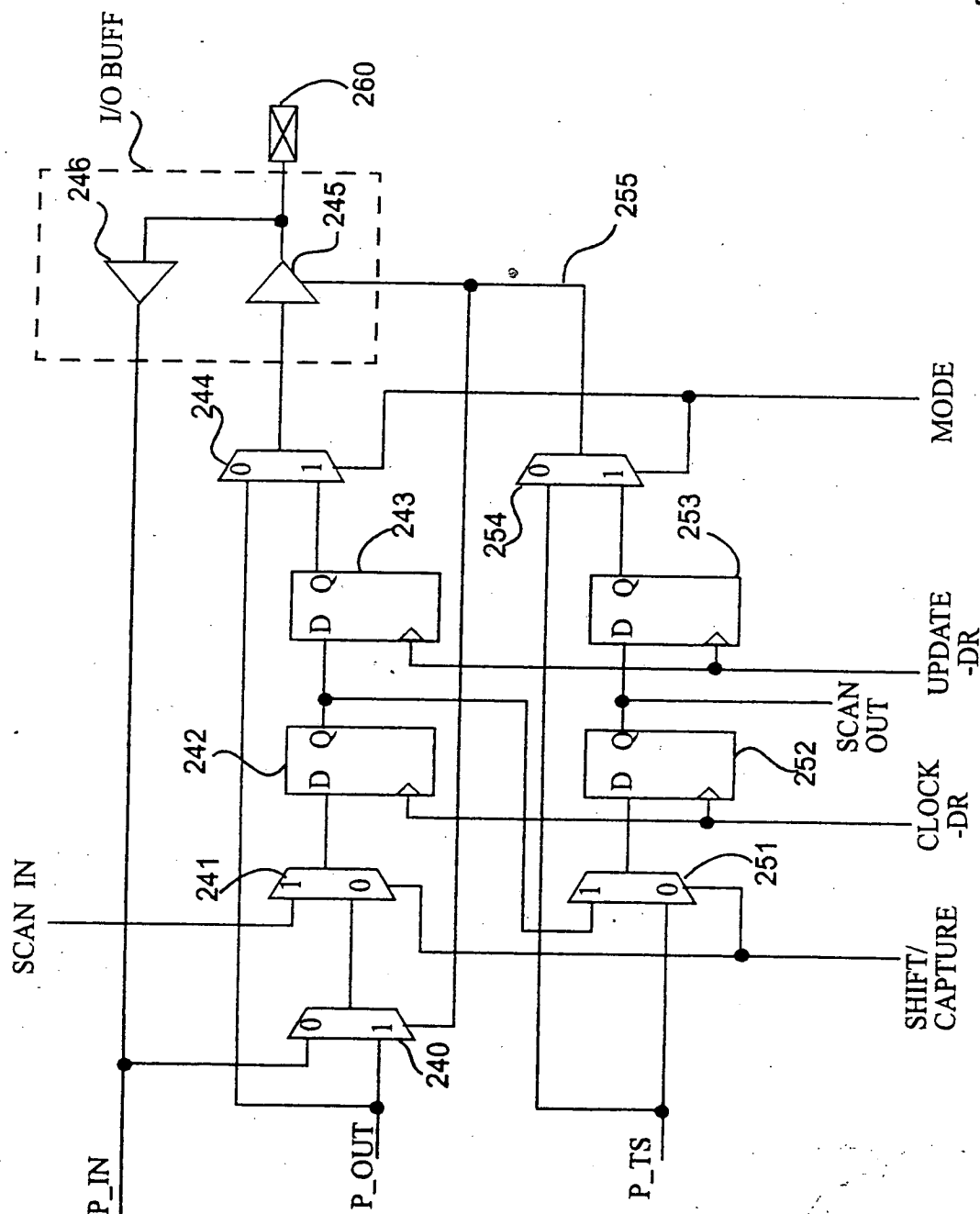
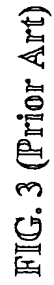


FIG. 2 (Prior Art)



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Attorney for the Applicant*

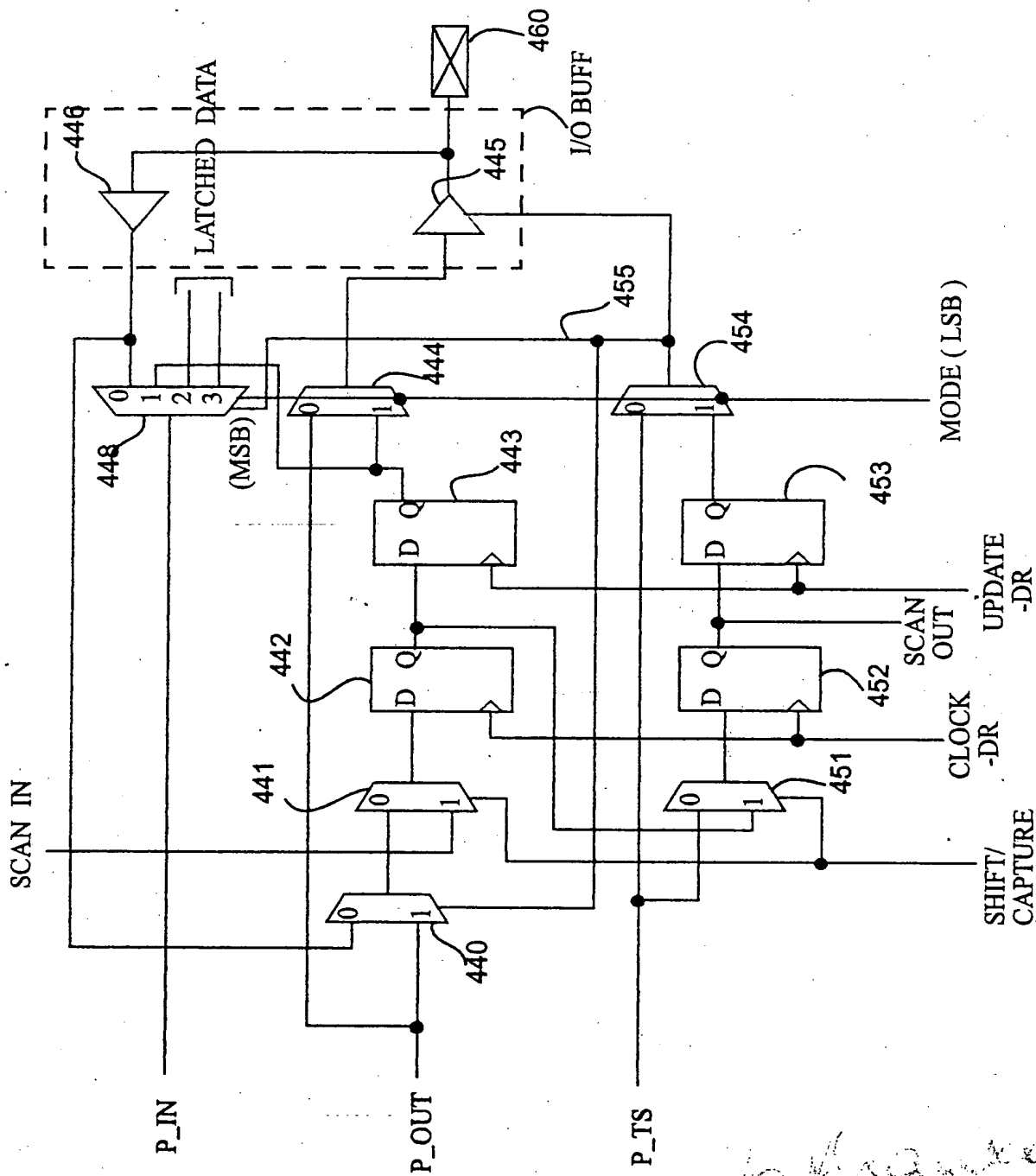


FIG. 4

*Of Anand And Anand Advocates
Attorney for the Applicant*

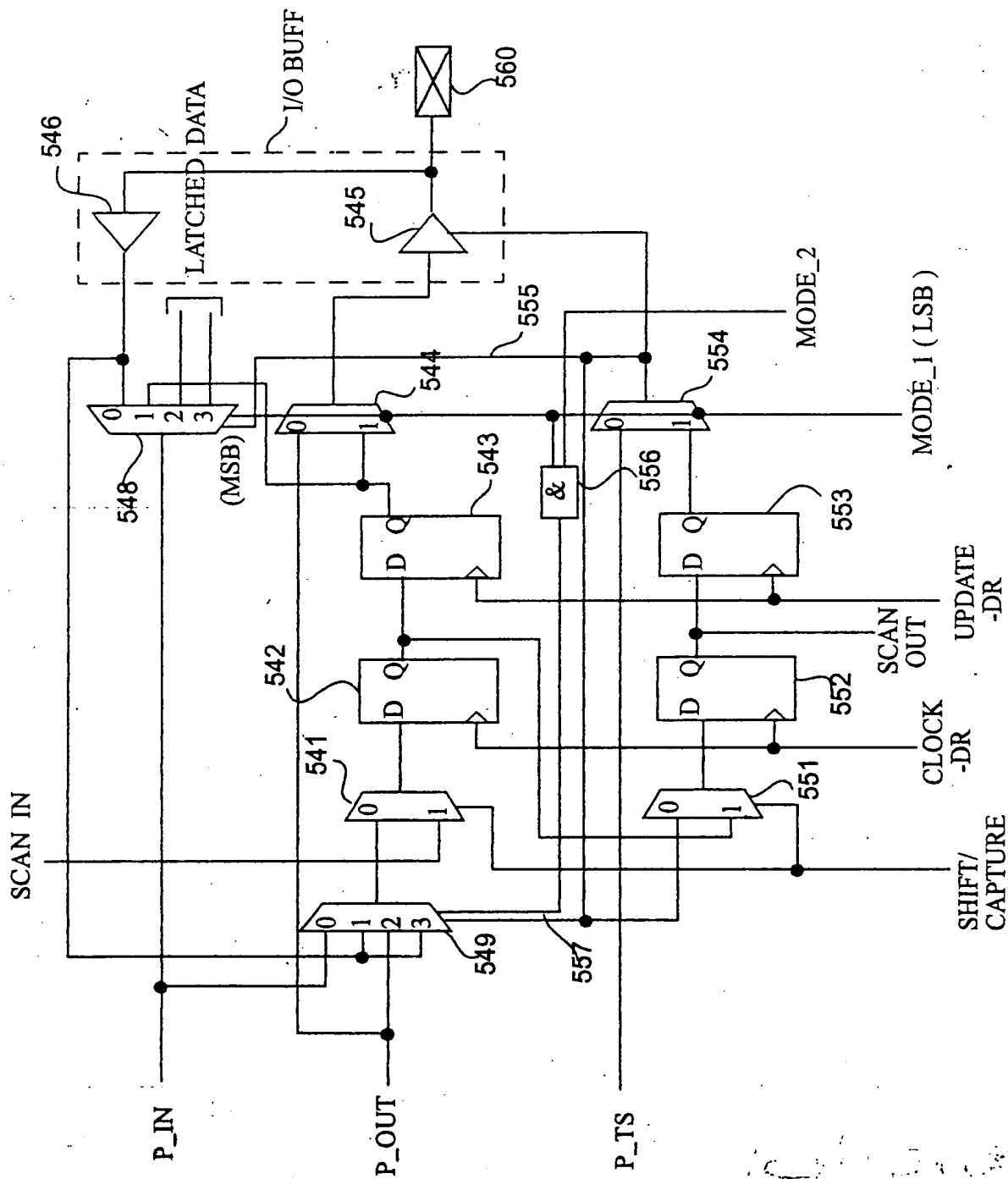


FIG. 5

*Of Anand And Anand Advocates
Attorney for the Applicant*

